Cooperative Exploration With Under-actuated Autonomous Vehicles in Hazardous Environments

Completed Technology Project (2016 - 2019)

Project Introduction

Our proposal seeks to demonstrate new methods for exploration using coordinated heterogeneous vehicle platforms. These methods rely on real-time automated mission re-planning, incorporating environmental and vehicle state data to maximize information gain while responding to risk/uncertainty and evolving science goals. This research is relevant to NASA because it decreases the need for human intervention, enabling under-actuated robotic platforms to complete survey and manipulation tasks in complex or hazardous environments which have previously required human teleoperation of highly maneuverable vehicles. This mode of operation is particularly important for robotic exploration in dynamic environments that, like Earth's subsea, are not amenable to radio-frequency teleoperation because of electromagnetic signal attenuation, or excessive communications latency. Our research will emphasize minimalist hardware through increased reliance on autonomous analysis, navigation, and planning. This is directly transferable to planetary explorers which must operate under similar power, size, and telemetry constraints. We will demonstrate these new capabilities at Kolumbo, the most active submarine volcano in the Mediterranean basin. This underwater caldera is a complex, hazardous environment that is a suitable analog for autonomous risk-aware exploration of other planetary bodies containing liquid water. As part of this demonstration we will explore for life forms in and around carbon-dioxide accumulating subsea pools. These pools represent a previously unknown type of marine habitat recently discovered by our team (Camilli, Nomikou, et al, 2015). The extent and composition of these acidic pools, as well as their associated chemolithoautotrophic communities are poorly understood. Our demonstration operations will provide a unique opportunity to characterize life which flourishes in extreme hypercapnia. Insights gained here will provide new perspectives on the biological context of Earth's precambrian evolution to an oxidizing atmosphere and possible life on other planetary bodies where photosynthetic carbon fixation is not possible. We propose to use heterogeneous oceanographic platforms analogous to those used in planetary exploration: a surface vessel (comparable to a remote sensing orbiter), an AUV glider (a long-range reconnaissance drone) and nUI, a light tether remotely operated vehicle (lander analog). The volcanic crater will be initially mapped using acoustic remote sensing from the surface vessel. Automated planners will assimilate these data (including potential areas of interest and hazards) to generate a mission plan for a hybrid AUV glider. The glider will be equipped with an underwater mass spectrometer to identify and localize chemical anomalies. The glider's limited payload and maneuverability motivates the use of onboard terrain aided navigation to maintain a safe distance from collision hazards while hunting for chemical signatures of interest. Autonomously interpreted water column data from the glider will inform spatially focused investigations using nUI equipped with an extensive science payload that includes stereo imaging cameras, sonar, and chemical sensors. Mission path planning/replanning and task scheduling of vehicles will be performed by a risk-aware planner that ensures safe operation by bounding

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Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

Planetary Science and Technology Through Analog Research

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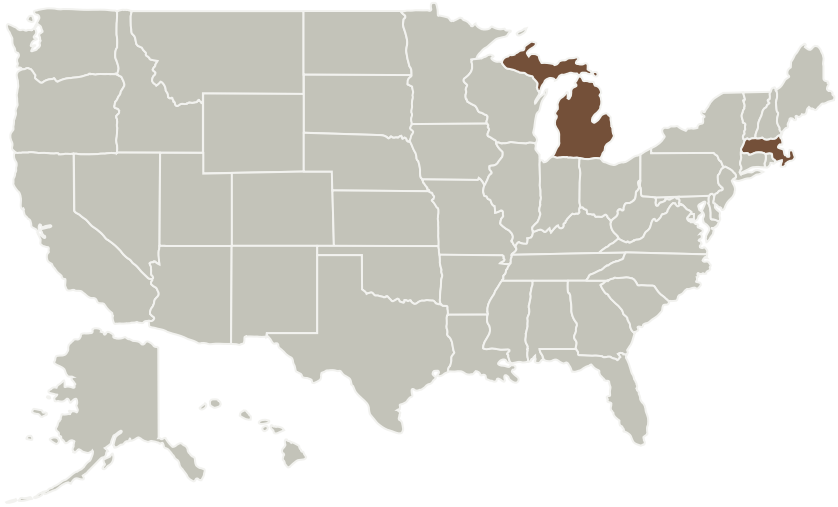
mission risk at operator specified levels. Technology development will also focus on enhanced perception and autonomy for imaging and precise spatial measurements in complex natural terrain that reduces the requirement to communicate state and science payload data during operations. nUI will apply real-time visual and acoustic mapping for risk-aware path planning in order to enable safe autonomous investigation of biological assemblages and geologic features in close proximity to hazardous areas. A robust education/outreach program will involve high school, undergraduate and graduate students.

Primary U.S. Work Locations and Key Partners



Primary U.S. Work Locations	
Massachusetts	Michigan

Project Management

Program Director:

Carolyn R Mercer

Program Manager:

Sarah K Noble

Principal Investigator:

Richard Camilli

Co-Investigators:

Brian Williams
Jennifer L Carter
Oscar Pizarro
Matthew Johnson-roberson

Technology Areas

Primary:

- TX04 Robotic Systems
  - TX04.2 Mobility
    - TX04.2.1 Below-Surface Mobility

Target Destination

Others Inside the Solar System